CRANE LOADING EVALUATION ON THE BASIS OF A PRIORI INFORMATION

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Rakenteiden Mekaniikka,
Vol. 23 No 4 1990,
s. 50 - 61

ABSTRACT

The paper describes the procedure of crane loading restoration after previous operational period of the crane. The procedure is based on the ranking correlation method and the analysis of the experts' opinions according to the concordance coefficient, signifiance of which is determined by Pearson's criterion χ^2. The procedure is illustrated by the example of practical investigation.

INTRODUCTION

To increase the safety of the operation of the loading cranes in the USSR there is an evaluation condition of the structural members after it's operating life. The time of inspection usually depends upon the operating conditions and it is within the limits of 18-25 years for the bridge and gantry cranes. The crane condition evaluation depends upon a number of parameters: The group of operating conditions, the loading, actual condition of structural members, progression of corrosion, condition of the machineries and the electrical equipment, crane track condition and some other parameters.

It is obvious from the point of view of accumulating of fatique damage on crack growth and also from the point of view of mathematical model of permanent service life according to the strength reliability criterion, that an accurate evaluation of the loading crane during it's operating service life is needed. According to design rules and safety requirements for the cranes, established in the USSR and other countries, recording of these parameters is not provided.

The most efficient way of solving this problem is mounting on a crane a system of diagnostic devices for monitoring both the structural members and the machinery from the very beginning of the crane service life. However, up to now we have to re-establish as much as possible the real crane loading for the previous years of its work. Character of crane loading, as the practice of the most industries shows, appears to be a random and stochastic variable, with the exeption of the field of industry with "rigid" technological cycle. In this field crane loading for the previous years could be re-established by the interpolation method on the basis of the registered crane loading of today.

For all other cases some other methods of obtaining the real statistic information are to be found.

METHOD

We suggest a prior information system with subsequent method of rank correlation and evaluation of experts' co-ordinated conclusion on the basis of the concordance coefficient. The realization of this system makes it necessary to define a circle of experts, whose judgements would play a decisive role in the crane loading evaluation.The most efficient experts of this kind may be people dealing with the cranes (crane operator, technologist, foreman of a shop area, etc.).

The method of preliminary inquest helps us to find out some possible variables of the lifted loads and their frequency during the fixed time interval. Such intervals may be a working shift, twenty-four hours, a month or any other logically completed and repeated in cycles period of time. Questionnaires are composed on the basis of the information obtained and in accordance with the desirable stages of equivalent loading sum. For instance, we want to build the loading sum of the 5-ton crane with the stages: 1 - loads up to 2 tons, 2 - loads within the limits of 2 - 3 tons, 3 - loads within the limits of 3 - 4 tons, 4 - loads of more than 4 tons. In accordance with the preliminary a prior information an average frequency on appearance of any from the given loads during the fixed time interval is chosen.

n factors in frequence are calculated for each fixed load in accordance with the chosen coefficients of variation. All the preliminary information should be represented in the form of the questionnaire cards (see Fig. 1). The frequences B, C, D, F, B_1, C_1, D_1, F_1, B_2, etc. are chosen for any separate crane depending upon the crane usage, the average a prior frequency and the given coefficient of variation.

Each of the experts is given a questionnaire card (see Fig.1). Choosing the most probable, from his point of view, frequency of load appearance, which corresponds to each stage of loading sum, the expert suggests the ranks within the limits from 1 up to n. The most probable factor gets the rank 1 and the next increase up to n. In case the expert can't show preference to a single factor and considers two or more factors to be equal, they are estimated the same ranks. For example, two factors of the most probability may get the same rank equal to 1,5.

After having carried out the ranking procedure it is necessary to clear out how much the experts' opinions would concide; this coincidence should be proved by corresponding statistic evaluation. In a case when there is no coincidence, it is necessary to increase a number of experts and to change the equivalent loading sum ranks values and the frequences of appearance of some other loads. After this the ranking procedure is repeated.

Definition of coincidence criterion - concordance coefficient W, ranking procedure and determination of rank correlation coefficients are usually carried out according to Kendall or Spearman. Concordance coefficient is determined by the formula:

$$W = \frac{s(d^2)}{\frac{1}{12} m^2 (n^3 - n) - m \sum_{j=1}^{m} Tj} \qquad (1)$$

Concordance coefficient is always within the limits from 0 up to 1. In case W = 0 there is no coincidence in experts' opinions, if W = 1 there is complete consent, ranking wholly coincidens.

Calculation of concordance coefficient goes as follows. Sums of Ranks are calculated by $\sum_{j=1}^{m} X_{ji}$, X_{ji} - value i-of the factor j- of the expert.

The mean value of summarized ranks $\frac{1}{2}$ m(n+1) is calculated where m - a number of experts; n - a number of factors.

The differences between each sum of ranks and the mean value of summarized ranks are calculated by

$$d_i = \sum_{j=1}^{m} x_{ij} - \frac{1}{2} m (n+1) \tag{2}$$

Then the sums of the squares of these differences are calculated by

$$s(d^2) = \sum_{i=1}^{n} d_i^2 = \sum_{i=1}^{n} [\sum_{j=1}^{m} x_{ij} - \frac{1}{2} m (n+1)]^2 \tag{3}$$

In case when all the experts do the same ranking, parameters $s(d^2)$ has maximum value

$$S_{max} (d^2) = \frac{1}{12} m^2 (n^3 - n) \tag{4}$$

In cases of co-ordinated ranks, which seems to be a usual practice of ranking, it is necessary to find out the value

$$T_j = \frac{1}{12} \sum_{k=1}^{m} (t_k^3 - t_k) \tag{5}$$

where t_k - the number of the same ranks under j - ranking. Substituting the values of equations 2, 3, 4 and 5 into the equation 1, we get the value of concordance coefficient.

Concordance coefficients W obtained usually differ greatly from 0, which leads to conclusion that in the loading evaluation there is a coincidence of opinions of experts. Experimental practice shows that the concordance coefficients, where values $W \geq 0,5$, should be recommended.
Statistic value of the concordance coefficient can be estimated according to the criteria F by Fisher or χ^2 by Pearson.

With co-ordinated ranks the criterion can be estimated by the equation

$$\chi^2_W = \frac{s(d^2)}{\frac{1}{2}\ mn\ (n+1) - \frac{1}{n-1} \sum_{j=1}^{m} T_j} \tag{6}$$

or

$$\chi^2_W = m\ (n-1)W \tag{7}$$

Comparison of criterion values χ^2_W obtained for each stage of loading sum as usually done with the table value of that criterion, calculated for the 5 per cent value level where a number of degrees of freedom $f = n - 1$.

In case the table value of $\chi^2_{0,95}$, is less than corresponding design value χ^2_W, we may state with 95 per cent probability that the experts' opinions on the point of frequency appearance under corresponding loading during the definite time period correspond to the concordance coefficient value W.

RESULTS

The results of practical investigations of the 5-ton bridge crane operating at a machine-building plant can illustrate the procedure above-mentiond.

The values of the concordance coefficients, criteria χ^2_W and $\chi^2_{0,95}$ are shown in Table 1. Analyzing the results obtained we may see that the values of the concordance coefficients for all of the equivalent loading sum stages are different, though their values exceed 0,5. Estimating the values of the criteria of Pearson χ^2_W and $\chi^2_{0,95}$ we may observe that all the coefficients have the values with 95 per cent probability. All above-mentioned allows us to arrange the values of all factors for each loading sum stage accordinly to their summarized ranks. The histograms based on a priori information obtained are shown in Fig. 2.

On the basis of the histogram factors with maximum difference values $\Sigma X_{max} - \Sigma X_{ij}$ was built a loading sum showing the crane operation during a shift (see Fig. 3).

Along the horizontal axis the real time is fixed, which is equal to the time of the average cycle of crane operation in accordance with a technological process. In some cases real time values may be substituted for the number of the operational includings of different mechanisms in the process of loading operations, corresponding to the definite stage of loading sum. After all, the notation of co-ordinate axes of equivalent loading sum depends on real mathematical model which will be the base of the modelling of the operation process, having in mind the evaluation of the permanent working capacity of mean-cycles-between failures.

CONCLUSIONS

Considering the real situation of crane loading restoration after previous operational period we suppose the procedure mentioned to be the only one in the case when there are no devices or log books for loading recording.

REFERENCES

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Table 1.

No No	Group notation	Condordance coefficient value W	Degree of fredom f	Value of Pearson criterion for concordance coefficient χ^2_W	Table value of Pearson criterion for 5 per cent level of signifiance $\chi^2_{0,95}$
1	Loads more than 4 tons in a shift	0,826	4	61,4	13,3
2	Loads from 3 tons up to 4 tons in a shift	0,758	4	54,5	13,3
3	Loads from 2 tons up to 3 tons in a shift	0,679	4	48,9	13,3
4	Loads up to 2 tons in a shift	0,812	4	57,5	13,3

Factor No	Loads more than 4 tons	Rank
1	B times a shift	
2	C times a shift	
3	D times a shift	
...	....	
n	F times a shift	

Factor No	Loads within the limits from 3 up to 4 tons	Rank
1	B_1 times a shift	
2	C_1 times a shift	
3	D_1 times a shift	
...	....	
n	F_1 times a shift	

Factor No	Loads within the limits from 2 up to 3 tons	Rank
1	B_2 times a shift	
2	C_2 times a shift	
3	D_2 times a shift	
...	....	
n	F_2 times a shift	

Factor No	Loads up to 2 tons	Rank
1	B_3 times a shift	
2	C_3 times a shift	
3	D_3 times a shift	
4	....	
n	F_3 times a shift	

Fig. 1 Questionnaire cards

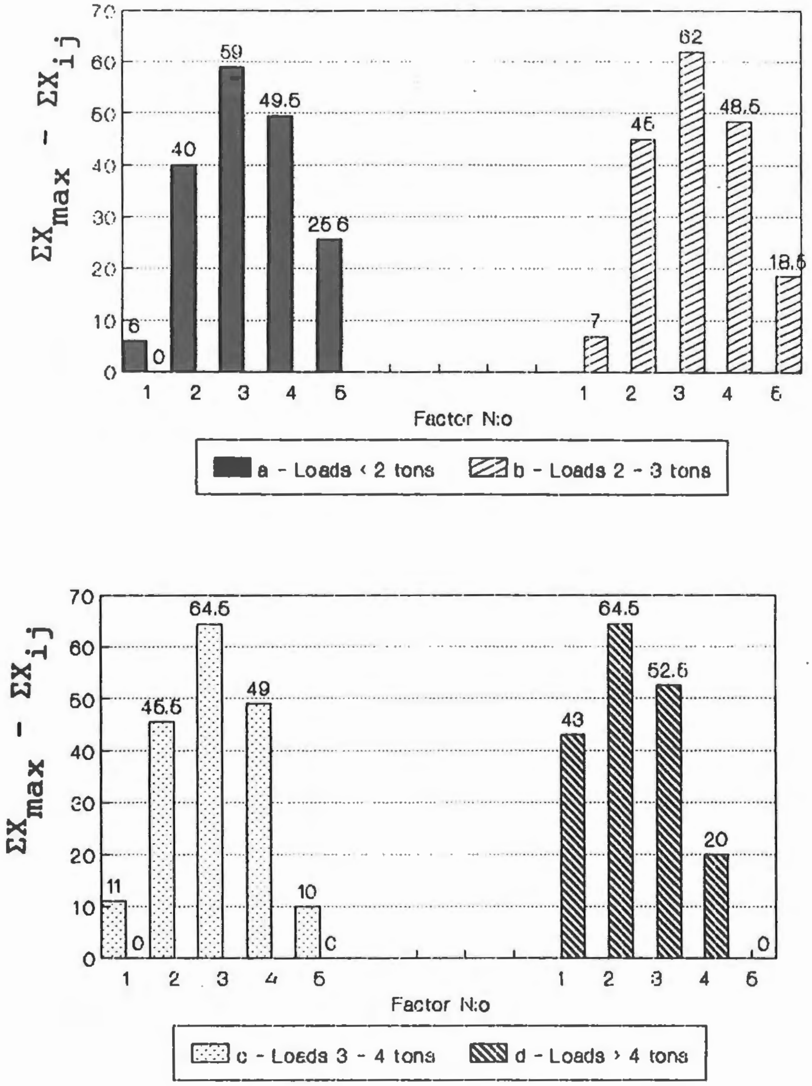

Fig.2 A priori histograms

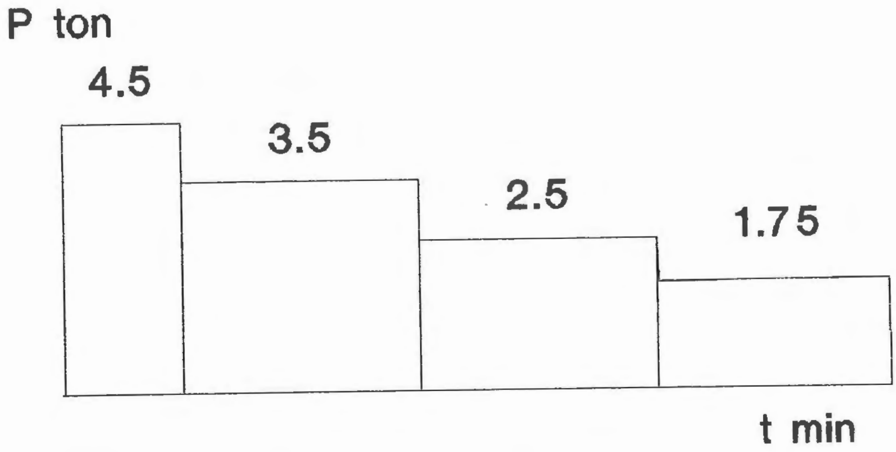

Fig 3. Diagram of loading sums in a shift

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